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Subject Pre-Final Revised Phase 1a Report Addendum

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Hi Chris - the pre-final redline version of the revised report addendum is attached as a pdf file. Please review the final edits and let me know if you have any comments to the revised text. The TOC page numbers will be finalized once the redline-strikeout is deleted.

I look forward to wrapping this one up!

Regards, Sharon



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Revised Report Addendum for Additional Data Collection in the Phase 1A Area

**Omega Chemical Superfund Site
Whittier, California**

March 9, 2005

Submitted to:

U.S. Environmental Protection Agency
Region IX

Prepared for:

Omega Chemical Site PRP Organized Group

Prepared by:

CDM

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Project No. 10500-37240.T1.GW.REPORT

The information contained in the document *Revised Report Addendum for Additional Data Collection in the Phase 1a Area Omega Chemical Superfund Site*, dated March 9, 2005, has received appropriate technical review and approval. The conclusions and recommendations presented represent professional judgments and are based upon findings from the investigations and sampling identified in the report and the interpretation of such data based on our experience and background. This acknowledgement is made in lieu of all warranties, either expressed or implied. The activities outlined in this report were performed under the supervision of a California Registered Geologist.

Reviewed and Approved by:

Sharon Wallin, R.G.
Project Manager

Contents

Section 1	Introduction	1-1
1.1	Background	1-1
1.2	Purpose and Objective	1-4
1.3	Organization of Report	1-4
Section 2	Field Procedures.....	2-1
2.1	Task 1 - Aquifer Testing and Water Quality Sampling and Analysis	2-1
2.1.1	Aquifer Testing	2-1
2.1.2	Water Quality Sampling and Analysis	2-3
2.2	Semi-Annual Monitoring Well Sampling and Analysis	2-3
2.3	Drilling and Soil Sampling	2-6
Section 3	Data Presentation and Evaluation	3-1
3.1	Lithologic Data	3-1
3.2	Water Level and Groundwater Elevation Results	3-4
3.3	Quarterly and Semi-Annual Groundwater Sampling Analytical Results	3-5
3.3.1	Chlorinated VOCs	3-5
3.3.2	Aromatic VOCs	3-9
3.3.3	Semi-VOCs, Pesticides, and Metals	3-10
3.3.4	Emerging Compounds	3-10
3.3.5	Biodegradation/Natural Attenuation Parameters	3-11
3.4	Soil Sampling Analytical Results	3-11
3.5	Aquifer Testing	3-11
3.5.1	Water Quality Sampling and Analysis	3-12
3.5.2	Evaluation of Aquifer Parameters	3-13
3.6	Quality Assurance/Quality Control and Data Validation	3-16
Section 4	Conclusions and Recommendations	4-1
4.1	Conclusions	4-1
4.1.1	Groundwater Flow Direction and Gradients	4-1
4.1.2	Groundwater Sampling Results	4-1
4.1.3	Soil Sampling Results	4-2
4.1.4	Fate and Transport	4-2
4.1.5	Aquifer Characteristics	4-5
4.2	Recommendations	4-8
Section 5	References.....	5-1

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Appendices

Appendix A	Boring/Well Construction Logs, MIP Screening Results, and Electric Logs
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Appendix B	Completed Field Forms
Appendix C	Well Survey Data
Appendix D	Analytical Reports and COCs
Appendix E	Aquifer Test Data
Appendix F	Fate and Transport
Appendix G	Hydrographs and Time-Series Plots
Appendix H	Data Validation

List of Figures

Figure 1-1	Site Location Map.....	Follows Page 1-4
Figure 1-2	Vicinity Map	Follows Page 1-4
Figure 1-3	Phase 1a Area Map	Follows Page 1-4
Figure 3-1	Monitoring Well Location Map	Follows Page 3-16
Figure 3-2	Groundwater Contour Map - May 2001	Follows Page 3-16
Figure 3-3	Groundwater Contour Map - June 2001	Follows Page 3-16
Figure 3-4	Groundwater Contour Map - July 2001	Follows Page 3-16
Figure 3-5	Groundwater Contour Map - August 2001	Follows Page 3-16
Figure 3-5	Groundwater Contour Map - September 2001	Follows Page 3-16
Figure 3-7	Groundwater Contour Map - October 2001	Follows Page 3-16
Figure 3-8	Groundwater Contour Map - November 2001	Follows Page 3-16
Figure 3-9	Groundwater Contour Map - December 2001	Follows Page 3-16
Figure 3-10	Groundwater Contour Map - January 2002	Follows Page 3-16
Figure 3-11	Groundwater Contour Map - February 2002	Follows Page 3-16
Figure 3-12	Groundwater Contour Map - March 2002	Follows Page 3-16
Figure 3-13	Groundwater Contour Map - April 2002	Follows Page 3-16
Figure 3-14	Groundwater Contour Map - August 2002	Follows Page 3-16
Figure 3-15	Groundwater Contour Map - February 2003	Follows Page 3-16
Figure 3-16	Groundwater Contour Map - August 2003	Follows Page 3-16
Figure 3-17	Groundwater Contour Map - February 2004	Follows Page 3-16
Figure 3-18	Groundwater Contour Map - August 2004	Follows Page 3-16
Figure 3-19	Groundwater Analytical Results for Selected VOCs ..	Follows Page 3-16
Figure 3-20	Groundwater Analytical Results for Emerging Compounds	Follows Page 3-16
Figure 3-21	Well and Cross-Section Locations	Follows Page 3-16
Figure 3-22	Cross-Section A-A'	Follows Page 3-16
Figure 3-23	Cross-Section B-B'	Follows Page 3-16
Figure 3-24	Cross-Section C-C'	Follows Page 3-16
Figure 3-25	Three-Dimensional View of Lithology	Follows Page 3-16

List of Tables

Table 3-1	Well Construction Details	Follows Page 3-16
Table 3-2	Water Level and Groundwater Elevation Data	Follows Page 3-16
Table 3-3	Chlorinated VOCs Analytical Summary Groundwater Analytical Results	Follows Page 3-16
Table 3-4	Aromatic and Other VOCs Analytical Summary Groundwater Analytical Results	Follows Page 3-16
Table 3-5	Pesticide and SVOC Analytical Summary Groundwater Analytical Results	Follows Page 3-16
Table 3-6	Metals Analytical Summary Groundwater Results	Follows Page 3-16
Table 3-7	Cyanide, Hexavalent, Chromium, Perchlorate and 1,4-Dioxane Analytical Summary Groundwater Analytical Results	Follows Page 3-16
Table 3-8	Biodegradation and Natural Attenuation Parameters Groundwater Analytical Results	Follows Page 3-16
Table 3-9	Biodegradation and Natural Attenuation Field Results	Follows Page 3-16
Table 3-10	VOCs and 1,4-Dioxane Analytical Summary Soil Analytical Results	Follows Page 3-16
Table 3-11	Estimated Aquifer Parameters	Follows Page 3-16

Section 1

Introduction

On behalf of the Omega Chemical Site PRP Organized Group (OPOG), Camp Dresser & McKee Inc. (CDM) has prepared this Report Addendum for Additional Data Collection in the Phase 1a Area of the Omega Chemical Superfund Site (Site) (revised March 9, 2005). The Site is located at 12504 East Whittier Boulevard in Whittier, California (see Figures 1-1, 1-2, and 1-3 for illustrations of Site location, vicinity, and Phase 1a area, respectively). The activities described in this document were performed in partial fulfillment of Tasks 1 and 3 of the Statement of Work included in Consent Decree No. 00-12471 between USEPA and OPOG. The Consent Decree was lodged on November 24, 2000 and entered into the U.S. District Court on February 28, 2001.

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1.1 Background

Under USEPA Administrative Order 95-15, OPOG performed an initial investigation of the Phase 1a area (see Figure 1-3) during June and July 1999 in accordance with the Final Sampling and Analysis Plan (SAP) Phase 1a Field Investigation (CDM, April 23, 1999). As part of the initial investigation, three groundwater monitoring wells (OW1b, OW2 and OW3) were installed in the Phase 1a area and sampled. An existing on-site well (OW1) was also sampled. In addition, well OW2 was test pumped at four steps (1.15, 2.50, 3.75, and 5.50 gallons per minute [gpm], respectively), with each pumping step lasting approximately one hour.

The results of the initial investigation were detailed in the USEPA-approved Phase 1a Pre-Design Field Investigation Report (CDM, October 13, 1999). The Phase 1a report recommended the following to assist in selecting the most appropriate location for groundwater containment:

- Additional confirmatory sampling to verify the volatile organic compound (VOC) concentrations detected in newly-installed Omega well OW1b.
- Additional investigations to further understand hydraulic conductivity and transmissivity conditions along or downgradient of Putnam Street.
- Installation of a sentinel well on Washington Boulevard to characterize the lateral variability of hydrostratigraphic conditions and assist in determining if the low permeability conditions indicated at OW2 and OW3 are laterally continuous and persistent, or if preferential pathways of higher hydraulic conductivity exist.

With the approval of the Phase 1a Report, OPOG completed all work required by Order 95-15 and negotiated the current Consent Decree (No. 00-12471) with USEPA.

In accordance with Task 3 of the current Consent Decree, OPOG installed four downgradient wells (formerly referred to as sentinel wells). The four wells (OW4a, OW4b, OW5 and OW6) were installed during March through August 2001 in accordance with the USEPA-approved Downgradient Well Installation and

Groundwater Monitoring SAP (CDM, April 20, 2001). The Downgradient Well SAP also specified the collection of quarterly groundwater samples and monthly water level monitoring for one year from all Omega wells. Groundwater samples were collected from the Omega wells during mid-May, mid-August, and mid-November 2001 and mid-February 2002.

In May 2001, USEPA requested that OPOG install and sample an additional groundwater monitoring well upgradient of the site. Additional data requirements for the proposed groundwater remedy were also discussed in a Technical Memorandum from OPOG to USEPA dated October 31, 2001. The Technical Memorandum identified the following additional data requirements:

- Installation of a third monitoring well at Putnam Street, between wells OW2 and OW3, to verify the lateral distribution of VOCs at this location and to collect additional hydrostratigraphic and hydraulic data at this location;
- Performance of single well aquifer recovery tests at wells OW2, OW3, OW4a and the new Putnam Street well location to provide better estimates of hydraulic conductivity at these locations; and
- Addition of 1,4-dioxane, metals, bioparameters (e.g., electron donors and receptors), total dissolved solids (TDS), total organic carbon (TOC), and chemical oxygen demand (COD) to the analytical suite for the next round of sampling at wells OW1, OW1b, OW2, OW3, OW4a and OW4b.

Wells OW7 (upgradient well) and OW8 (Putnam well) were installed and sampled in March 2002. Well drilling, installation, development, and sampling activities were performed in accordance with the procedures specified in the Downgradient Well SAP.

Following the completion of quarterly sampling and monthly water level monitoring in mid-February 2002, OPOG initiated semi-annual sampling of all 10 Omega wells. Semi-annual sampling was performed during mid-August 2002 and mid-February 2003 in accordance with the SAP Addendum for Additional Data Collection in the Phase 1a Area (CDM, May 31, 2002). The additional data requirements listed above from the Technical Memorandum formed the basis of the activities described in the SAP Addendum. In addition to groundwater monitoring, the SAP Addendum also specified short-term constant discharge and recovery aquifer testing and sampling of wells OW2, OW3, OW4a and OW8. Aquifer testing and sampling of these wells was performed mid-March 2003.

A draft Report Addendum presenting the results of the additional data collection activities (semi-annual groundwater sampling and water level monitoring, and aquifer testing and sampling), in addition to prior quarterly groundwater sampling and monthly water level monitoring activities was submitted to USEPA in June 2003 (CDM, June 27, 2003, Report Addendum for Additional Data Collection in the Phase 1a Area). USEPA comments to the draft report were provided in correspondence

dated October 15, 2003. USEPA requested that these comments be incorporated into future data collection activities and subsequent versions of the Phase 1a report. This document, therefore, has been revised to address the USEPA's comments to the draft report.

On November 11, 2003, a memorandum describing the proposed scope of work for additional data collection activities in the Phase 1a area was submitted to USEPA. The memorandum proposed the following additional data collection activities in the Phase 1a area: eight off-site soil borings (four at the Terra Pave property and four along Putnam Street), the installation of piezometers at two of the Putnam Street boring locations, and a 12-hour constant rate aquifer test of well OW8. The memorandum also recommended that four on-site borings proposed in the On-Site Soils RI/FS Work Plan (CDM, September 29, 2003) be advanced and sampled early (i.e., prior to initiation of the RI/FS field program). USEPA comments to the memorandum were provided in correspondence dated December 2, 2003.

Deleted: The work proposed in the memorandum was implemented during October and November 2003.

The proposed additional data collection activities in the Phase 1a area were discussed with USEPA during a kick-off meeting at the Site on September 29, 2003 with the newly-assigned Remedial Project Manager. The work was initiated in late-October 2003 in order to perform the work concurrent with the initiation of drilling associated with the On-Site Soils RI/FS field program. The proposed additional data collection included additional sampling from several deep Site soil borings proposed in the USEPA-approved On-Site Soils Work Plan. During March and April 2004, additional background water-level data were also collected from wells OW1, OW1b, OW4a, OW4b, OW7, and OW8 in order to evaluate the typical range in variation in water levels at the site.

Additional semi-annual sampling was also performed during August 2003, February 2004, and August 2004. In addition, as requested by USEPA, an additional deeper well (OW8b) was installed to a depth of in August 2004 in order to evaluate potential impacts to the deeper zone. The results of these additional activities have also been incorporated into this revised report.

Boring/Well Construction Logs for all 11 Omega wells are provided in Appendix A. Electric logs for wells OW4b and OW8b, which were drilled using mud rotary methods, are also provided in Appendix A.

USEPA has also been performing a regional groundwater investigation in areas downgradient of the Site to identify additional sites which may have contributed to groundwater contamination in the area. Phase 1 of the regional groundwater investigation was performed for USEPA by Roy F. Weston, Inc. (Weston) during the period from August 15 through November 2, 2001. The Phase 1 investigation included the analysis of 81 in-situ groundwater samples collected using a push-probe drill rig, temporary well screen, and bailer. In addition, 30 exploratory boring were advanced during the Phase 1 investigation using a cone penetrometer (CPT) drill rig. The results of the Phase 1 investigation were presented in the Phase 1 Groundwater

Characterization Study (Weston, February 2002). Weston also installed and sampled 18 groundwater monitoring wells as part of a subsequent Phase 2 investigation. USEPA also collected split samples for laboratory analysis from all Omega wells during the quarterly and semi-annual sampling events. Sampling of the regional wells is currently being performed for USEPA by CH2MHill.

1.2 Purpose and Objective

As described above and in accordance with the objectives and scope of work detailed in the Consent Decree, the purpose of the investigation detailed in this Report Addendum was to collect additional data (e.g., lithologic, water quality, aquifer hydraulics, etc.) in order to assist in the selection of the groundwater remedy in the Phase 1a Area. This document summarizes the results of the additional investigation.

1.3 Organization of Report

This report is organized into five sections, as follows:

- Section 1 - Introduction
- Section 2 - Field Procedures
- Section 3 - Data Presentation and Evaluation
- Section 4 - Conclusions and Recommendations
- Section 5 - References
- Appendix A - Boring/Well Construction Logs, MIP Screening Results, and Electric Logs
- Appendix B - Completed Field Forms
- Appendix C - Well Survey Data
- Appendix D - Analytical Reports and COCs
- Appendix E - Aquifer Test Data
- Appendix F - Fate and Transport
- Appendix G - Hydrographs and Time-Series Plots
- Appendix H - Data Validation

Figures and tables are provided at the rear of each section where they are first discussed. In response to USEPA's October 15, 2003 comments, detailed cross-sections (Figures 3-22 and 3-23) were developed for this revised report. The Site base map was also revised to more accurately depict the location and configuration of

buildings and streets in the surrounding areas. The groundwater elevation contour maps and all other Section 3 figures have been revised to incorporate the new base map features.

Section 2

Field Procedures

As discussed in Section 1, two tasks were performed during the initial Phase 1a field investigation in accordance with the SAP Addendum:

- Task 1 - Aquifer Testing and Water Quality Sampling and Analysis
- Task 2 - Semi-Annual Monitoring Well Sampling and Analysis

Additional tasks recommended in the November 11, 2003 memorandum were also performed, as follows (for ease of review, the additional task has been identified as Task 3 in this document):

- Task 3 - Drilling and Soil Sampling

Task 1 above was also expanded per the November 11, 2003 memorandum to include additional longer-term testing of well OW8. A brief discussion of field procedures is provided below.

2.1 Task 1 - Aquifer Testing and Water Quality Sampling and Analysis

Wells OW2, OW3, OW4a and OW8 were tested during the period from March 10 through March 14, 2003 using the single borehole recovery method. An aquifer performance test was conducted by pumping well OW8 and monitoring the response at wells OW1b, OW2, OW3, OW4a, and OW7, and piezometers PZ-1 and PZ-2 between November 19 and November 20, 2003. In addition, water levels were monitored using a pressure transducer during March and April 2004 at wells OW1, OW1b, OW4a, OW4b, OW7 and OW8 to assess background groundwater level fluctuations. Section 2.1.1 provides procedures for aquifer testing, while Section 2.1.2 provides the procedures for the water quality sampling.

2.1.1 Aquifer Testing

2.1.1.1 Single Borehole Tests

A submersible pump was used to perform a 4-hour single borehole aquifer performance test at each of the four well locations, with recovery measured until the water level at each tested well had recovered to within approximately 95 percent of its pre-test static condition.

CDM metered discharge during each test and collected totalizer readings at the beginning and end of the pumping period from an in-line flow meter. Due to some flow adjustments made during testing, a constant discharge rate was difficult to maintain for OW-2, 3, and 4A and totalizer readings were used to estimate the average pumping rate for the entire test period. Therefore, the average pumping rate calculated from the totalizer readings may not reflect the true rate at any specific

period during the test. Periodically during pumping, samples of the discharge water were collected for field measurement of pH, temperature, electrical conductivity, and turbidity. Field measurements were recorded on the Aquifer Pump Test Data sheets contained in Appendix B. Equipment decontamination was performed as described in Section 4.8 of the Downgradient Well SAP. The following average pumping rates were determined for each test:

- OW2 - 2.3 gpm
- OW3 - 1.34 gpm
- OW8 - 10.4 gpm
- OW4a - 10.3 gpm

Water levels prior to initiating each test and during the pumping and recovery phases of each test were monitored automatically using a data logger and transducer (In-Situ Mini-Troll™), and confirmed manually using an electric water level indicator. Equipment operation was performed in accordance with manufacturer's instruction manuals. Manual and transducer monitored water levels showed good agreement, so only the transducer data are used in the analysis, since the factory calibrated transducers provide accurate indications of the water level changes. Water levels fluctuations were minor and showed no significant trend, so no corrections were applied to the data. Manual water level readings were generally collected on a typical logarithmic progression (e.g., every minute during the first ten minutes of the test, every two minutes from 10 to 20 minutes into the test, every 5 minutes from 20 to 30 minutes into the test, every 10 minutes from 30 to 60 minutes into the test, etc.). The data logger also collected water level measurements using its pre-set logarithmic progression. Manual measurements are provided on the field forms contained in Appendix B.

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A total of 6,326 gallons of water were generated during the four tests. The water was pumped directly into a vacuum truck. Upon the completion of testing at each location, the purge water was transported under non-hazardous waste manifest to the Demenno/Kerdoon (DK) facility in Compton, California for recycling. Because well purge water from previous sampling events in 2001, 2002, and 2003 had also been recycled by the DK facility, a disposal profile had been established for the water and further analysis was not required prior to disposal.

2.1.1.2 Aquifer Performance Test

A multi-well aquifer performance test was conducted between November 19 and 20, 2003 by pumping well OW8 and monitoring water levels at wells OW1b, OW2, OW3, OW4a, and OW7, and piezometers PZ-1 and PZ-2. The aquifer pumping test was preceded by short term pumping to verify long term rates and to test equipment.

A submersible pump was used for all pumping of OW8. Flow at OW8 was monitored using an in-line flow meter with a totalizer. The flow rate was monitored and adjusted during the early part of the test to a nominal 11 gpm. Pumping rates did fluctuate during the first 2 hours of the test to rates as low as 5 gpm for short periods. Flow rates remained stable till near the end of the test, when a 90 second shutdown occurred during refueling of the generator. A total of 12,973 gallons of water were pumped over 1,184 minutes (19.73 hours), resulting in an average flow rate of 10.96 gpm. Owing to the presence of various organic compounds in the discharge water, it was necessary to containerize the pumped water in a portable tank for disposal at an off-site facility.

Water levels were monitored prior to testing, in addition to during the pumping and recovery periods at the noted wells using pressure transducers and data loggers. Initial settings for transducers were based on manual water level measurements. All analyses were conducted using the transducer readings. Water levels prior to the test varied only within a few hundredths of a foot, so no corrections were applied to the data. Additional monitoring was conducted during winter 2004 at several wells on site to assess the range in variation in water levels typical at the site.

2.1.2 Water Quality Sampling and Analysis

Water quality samples were collected from each pumped well just before the termination of pumping. One sample was collected from each well and submitted for analysis of the following parameters on a standard turnaround basis:

- VOCs plus acetone, Freon 11, Freon 12, Freon 113, MTBE (methyl-tertiary-butyl-ether) and Tentatively Identified Compounds (TICs) by Method 8260B
- 1,4-Dioxane by Method 8270M

The discharge rate was slowed to less than one gpm during sample collection. The sample containers were filled directly from the end of the discharge pipe. One sequential duplicate sample was also collected from well OW8 during the March 2003 testing. Sample collection and handling was performed as described in the following section. Analytical reports and completed COC forms for analytical samples collected during aquifer testing are contained in Appendix D.

2.2 Semi-Annual Monitoring Well Sampling and Analysis

In accordance with the SAP Addendum, all Omega wells will be sampled on a semi-annual basis until the Phase 1a Area treatment plant is operational. As previously discussed, semi-annual sampling was initiated during mid-August 2002. To date, five semi-annual sampling events have been completed (mid-August 2002, mid-February 2003, mid-August 2003, mid-February 2004, and mid-August 2004). Groundwater samples collected from the Omega wells and duplicates were analyzed for the

following parameters at a fixed-base laboratory during the five semi-annual sampling events performed to date:

- VOCs plus acetone, Freon 11, Freon 12, Freon 113, MTBE (methyl-tertiary-butyl-ether) and Tentatively Identified Compounds (TICs) by Method 8260B

In addition, groundwater samples collected from selected wells (OW1, OW1b, OW2, OW3, OW4a, OW4b, and OW8) were analyzed for 1,4-dioxane by Method 8270M during the mid-August 2002 and mid-February 2003 sampling events. During the three most recent sampling events (mid-August 2003 through mid-August 2004), samples for 1,4-dioxane analysis were collected from all Omega wells.

In accordance with Section 2.2 of the SAP Addendum and as described below, all wells were purged using a portable submersible pump and dedicated polyethylene tubing. Purge volume was determined by measuring the water level and bottom of each well, and then calculating three saturated casing volumes. The amount of water contained in the gravel pack was also estimated, multiplied by three, and added to the purge volume. At locations where the well pumped dry (i.e., OW1 and OW1b), the well was sampled later that day or early the next morning following water level recovery.

As previously described in Section 2.1.1, samples of the discharge water were collected periodically for field measurement of pH, temperature, electrical conductivity, and turbidity. Upon the completion of purging, with the exception of samples for VOC and 1,4-dioxane analyses, the discharge rate was lowered to less than 1 gpm and sample containers were filled directly from the end of the discharge tubing. The portable pump was then removed from each well and a pre-cleaned, disposable bailer lowered to the approximate middle of the perforated section was used to collect samples for VOC and 1,4-dioxane analyses. The sample containers were filled pouring directly from the top of the bailer, exercising care to minimize agitation.

Field measurements for all semi-annual sampling events are indicated on the Monitoring Well Purge and Sampling forms contained in Appendix B. Analytical reports and completed COC forms for analytical samples collected during the semi-annual sampling events are contained in Appendix D.

As indicated in the Technical Memorandum (OPOG, October 31, 2001), additional analyses for biodegradation/natural attenuation parameters and emerging compounds were also performed on groundwater samples collected from selected wells (OW1, OW1b, OW2, OW3, OW4a, OW4b and OW8) during the February 2003 semi-annual sampling event. Analyses of the field parameters listed below were performed in accordance with manufacturer's directions provided with each Direct Reading Instrument (DRI) and Hach Test Kit.

Biodegradation/Natural Attenuation Field Parameters

The following biodegradation/natural attenuation parameters were analyzed immediately in the field:

- Dissolved Oxygen (DO) *
- Redox (Eh) *
- Sulfate **
- Iron (II) **
- Alkalinity **
- Chloride **
- Hydrogen Sulfide **
- Carbon Dioxide **

* Indicates field analysis using a DRI (Orion 250A for Eh and YSI 55 for DO) .

** Indicates field analysis performed per manufacturer's instructions using a Hach Company (Loveland, Colorado) test kit.

Biodegradation/Natural Attenuation Analytical Parameters (fixed-base laboratory)

The following parameters were analyzed by a fixed-base laboratory:

- Nitrate/Nitrite (Method 300.0)
- Dissolved Organic Carbon (DOC, Method 415.1)
- Methane/Ethane/Ethene (if field tests indicated conditions were anaerobic)
(Methane by Method AM20GAX and Ethane/Ethene by Method AM18)

Sample handling was performed as indicated in Section 3 (Table 3-1) of the SAP Addendum. Laboratory samples for dissolved organic carbon analysis were collected in un-acidified containers, and filtering by the lab was indicated on the Chain of Custody (COC) form. Field personnel coordinated with the analytical laboratory to make sure that analyses with short holding times (e.g., nitrate/nitrite and hexavalent chromium) were analyzed within the required holding time.

In accordance with the SAP Addendum, bottles were filled for methane/ethane/ethene analyses and stored in an iced cooler pending evaluation of the dissolved oxygen measurements and ferrous iron (Fe II) field analytical results for the sampled wells. According to the SAP Addendum, in the event that anaerobic conditions were observed at a sampled well location (e.g., ferrous iron was detected during field testing and DO measurements were less than 1 mg/L), the bottles filled for methane/ethane/ethene analyses were to be submitted to the fixed-base laboratory for analysis. Methane/ethane/ethene are metabolic byproducts produced only under reduced, anaerobic environments. Methane is produced through carbon dioxide reduction and/or fermentation reactions, while ethane and ethane are innocuous end-products that result from the reductive dechlorination of chlorinated VOCs. In the

absence of anaerobic conditions, methane/ethane/ethene generation is likely be insignificant, therefore, analysis for these compounds was unwarranted. Based on evaluation of the field results, three samples (OW1, OW1b, and OW8) were selected for methane/ethane/ethene analyses.

Emerging Compounds (fixed-base laboratory)

The following additional parameters were also analyzed by a fixed-base laboratory:

- Hexavalent Chromium (Method 218.6)
- 1,4-Dioxane (Method 8270C)
- Perchlorate (Method 314.0)

Well Purging and Sampling Procedures

Each well was purged using a portable submersible pump and dedicated polyethylene tubing previously installed inside each Omega well. Upon the completion of purging, with the exception of samples for VOC and 1,4-dioxane analysis, all sample containers were filled directly from the end of the discharge tubing, with the discharge rate lowered to less than one gpm during filling of the sample containers.

Upon the completion of sample collection using the submersible pump, the pump was removed from the well and a pre-cleaned, disposable bailer lowered to the approximate middle of the perforated section. The bailer was used to collect samples for VOCs and 1,4-dioxane analyses. The groundwater contained in the bailer was poured directly into the sample containers, minimizing agitation. After sampling was completed, the bailer and line were discarded.

All samples were submitted for standard analytical turnaround time. Level 4 deliverables were requested on approximately 10 percent of the samples submitted for fixed-base laboratory analysis during each sampling event, in order to perform formal validation of the data. Data validation results are discussed in Section 3.6. The laboratory provided both electronic and hard copy reports.

Water Level Measurements

Water level measurements were also collected from the Omega wells prior to each sampling event. Water level measurements and water quality sampling activities were performed in accordance with the procedures specified in Sections 2.1.4 and 2.1.5 of the Downgradient Well SAP, respectively.

2.3 Drilling and Soil Sampling

Eight borings (GP1 through GP8) were advanced and sampled during October 2003 and January 2004 using the direct-push drilling method. Borings GP1, GP2, GP3, and GP6 were located on the Omega site, with borings GP5, GP5, GP7, and GP8 located on the adjacent Terra Pave property (direct-push boring locations are illustrated on Figure 3-21).

A specialized down-hole tool (Membrane Interface Probe [MIP]) was utilized at three of the boring locations (GP4 through GP6) to collect continuous total VOC screening information during drilling. The MIP screening results (see Appendix A) were used to select 3 to 4 soil samples per boring for laboratory analysis of VOCs. A fourth location (GP3) was originally proposed for MIP screening. During drilling at the location of GP3 (former 500 gallon kerosene UST), however, gravel backfill was encountered to a depth of 7 feet bgs. The boring was subsequently advanced to 35 feet bgs but had to be abandoned due to gravel falling down the boring which prevented advancing the boring below 35 feet bgs. The replacement boring (GP3A) was relocated a short distance to the south of the former UST location. Due to indications of contamination (i.e., odor) noted at location GP3, it was determined in the field to forego MIP screening at location GP3A and instead collect additional soil samples for VOC and 1,4-dioxane analyses. A total of eight soil samples were subsequently collected for laboratory analyses at approximate 10-foot intervals in the interval from 10 to 85 feet bgs.

Four borings (B1 through B4) were advanced along Putnam Street during November 2003 using the sonic drilling method. Each boring was continuously cored for lithologic description purposes. Two of the borings (B1 and B2) were converted to 2-inch diameter piezometers (PZ1 and PZ2, respectively).

Well OW8b was installed on Putnam Street during August 2004 using the direct mud rotary drilling method. During drilling, soil cuttings were collected from the drilling fluid and logged. Electric-logging (16 and 64-inch resistivity, 6-foot lateral resistivity, point, spontaneous potential, and gamma) was also performed in the boring after it had been advanced to its maximum depth (143 feet bgs). Following evaluation of the lithologic and geophysical logs, the well was installed and completed to a depth of 126 feet bgs.

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Boring and well locations are illustrated on Figure 3-21. Boring logs, well and piezometer completion details, and geophysical logs are provided in Appendix A. Survey results (wellhead location coordinates and elevation) for new well OW8b, new piezometers PZ1 and PZ2, and all other Omega wells is provided in Appendix C.

Section 3

Data Presentation and Evaluation

As previously discussed, wells OW7 and OW8 were installed in March 2002, with well OW8b installed in August 2004. These wells yielded additional information regarding subsurface conditions at the two locations presently being evaluated for extraction of impacted groundwater. In addition, during the period from May 2001 through February 2003, water level measurements were collected from Omega wells monthly for one year and then semi-annually for a year, totaling 17 separate events. Monitoring well locations are illustrated on Figure 3-1, with groundwater elevation contours for the 17 water level monitoring events illustrated on Figures 3-2 through 3-18. Selected VOC results and emerging compound results are illustrated on Figures 3-19 and 3-20, respectively.

Two piezometers (PZ1 and PZ2) were installed as observation points for the aquifer test using sonic drilling methods with continuous core retrieval. A deep zone well (OW8b) was installed adjacent to OW8 to evaluate the degree of hydraulic connection and relative contaminant concentrations between the two zones.

Well construction information has been summarized in Table 3-1, with water level measurements and groundwater elevation summarized in Table 3-2. Analytical results for all groundwater sampling events were input into the project's Access™ database, with analytical results summarized in Tables 3-3 through 3-8. Biodegradation/natural attenuation field results are summarized in Table 3-9. Soil sample analytical results are summarized on Table 3-10.

As previously discussed, the historical base map used to illustrate the groundwater elevation contours and other figures has been revised to more accurately depict the location and configuration of buildings and streets in the surrounding areas. The new basemap was developed using one-foot resolution orthonormalized and georeferenced aerial photography from the United States Geological Survey (USGS). Features including streets and building footprints were digitized from this orthophoto coverage to create basemap features. All maps and photos were maintained in NAD83 state plane coordinates. Wells and borings or other sample locations with survey, GPS or digitized coordinates in various projections were converted to NAD83 for plotting on the basemap.

3.1 Lithologic Data

The subsurface lithology at the location of new well OW7 is very similar to the lithology at locations OW1 and OW1b. As indicated on the lithologic logs contained in Appendix A, the subsurface materials at location OW7 consist primarily of clays and silty clays. The subsurface materials at the location of new well OW8 are comparable to the materials observed at locations OW2 and OW3, with silts and clays observed to an approximate depth of 54 feet below ground surface (bgs) and sand observed in the interval from 54 to 79 feet bgs. The subsurface materials adjacent to the screened

interval of well OW8 are slightly coarser-grained (very fine to coarse sands) than the subsurface materials adjacent to the screened interval of well OW2 (very fine to fine sands).

Additional lithologic data along Putnam Street obtained from piezometers PZ1, PZ2 and well OW8 indicate that the uppermost aquifer in this area is comprised of sand, silty sand and well graded gravel containing significant silt. The aquifer is interbedded, and in the area between PZ1 and PZ2 contains a finer grain interval separating the upper and lower portion of the aquifer. The deep well (OW8b) indicates that a 26 foot thick clay separates the upper aquifer from the next deeper sandy interval that was screened in this well. This unit may correlate with the low permeability unit separating the Gage and Jefferson aquifers, however, the nearest regional cross-section in Bullitin 104 suggests that this intervening unit is somewhat thicker.

The subsurface materials adjacent to the screened interval of well OW4a are generally coarser-grained (fine to coarse sands with some gravel), and consist of sands and silty sands interbedded with clays and silty clays. Due to flowing sands encountered at location OW4, the deeper well (OW4b) was drilled using the mud rotary drilling method vs. the hollow-stem auger method used to drill and install the other 9 Omega wells. An electric log was performed in the OW4b boring and is included in Appendix A. The electric log correlates well with the lithologic logs at location OW4.

Detailed geologic cross-sections were constructed approximately along the groundwater flow direction and orthogonal to this flow direction along Putnam Street. Figure 3-21 shows the plan view location of these cross-sections. Cross-section A-A' (Figure 3-22) extends along an approximate groundwater flow line extending from OW7, upgradient of the site, to OW4 downgradient of the site. Shallow deposits in the vadose zone consist primarily of silt and clay deposits. This section illustrates the presence of the two aquifer zones present at the site, separated by a low permeability confining zone. The upper aquifer zone appears to 'pinch out' in the area upgradient (east) of Putnam Street. A relatively thick sand sequence is observed at OW4 and OW8, that thins dramatically at borings GP-7 and GP-1. This sandy zone is absent at boring GP-2. The deeper sand zone is only observed at locations OW4 and OW8, which extended to a sufficient depth. Well OW1b extended to a similar depth, however, sandy lithologies were not encountered at this boring. Based on water levels at the OW4 and OW8 locations, where both deep and shallow zone completions are available, the groundwater elevations are significantly higher in the shallow aquifer. A similar difference in water level, with an indicated downward gradient was observed at the cluster at OW1/1b. This indicates that a significant confining zone limits flow between these zones. This issue will be discussed further in Section 3.3.1. An additional cross-section, B - B', (Figure 3-23) was prepared extending from OW-8B through I I-3, including wells OW-1 and OW-1B. This section also indicates that the upper zone pinches out. Well OW-1B was drilled to approximately elevation 70 ft MSL and encountered only clayey lithologies. The interval in the sensing zone for this well does have small percentages of gravel interspersed in a clay matrix near the

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bottom of the well, however, the small percentage of coarser material will not significantly increase the permeability of this unit. This is a similar elevation as the deeper aquifer encountered at OW-8B, which is screened from elevation 75 to 85 ft MSL in a well sorted fine to medium sand. Well OW-1B has a sensing zone that likely intersects the uppermost portion of the same interval intersected at OW-8B, implying that this deeper zone pinches out in a manner similar to the upper aquifer zone, or, if the deeper aquifer is present, it occurs at a greater depth. EPA is currently installing additional wells to define groundwater flow directions in the site vicinity. If these additional wells indicate that well OW-8B is downgradient of the site, then no further investigation of the potential for a deeper aquifer zone at the site is warranted, since OW-8B does not indicate the presence of high levels of contamination.

An additional cross-section was constructed approximately along Putnam Street, at a right angle to the general flow direction. Cross-section C-C' (Figure 3-24) incorporates boring logs available in EPA files for other sites. This section indicates that the shallow aquifer may pinch out to the north, since it was not encountered in borings north of H-7. The shallow aquifer configuration shows the presence of a lower permeability zone splitting the upper aquifer north of PZ1. Boring B-4 indicates a thick sand sequence suggesting that the lower permeability split was eroded, or never deposited, resulting in good hydraulic connection within the upper aquifer at this location. The uppermost sand unit within the upper aquifer appears continuous below the water table elevation from H-7 at the northern end to B-3 at the southern end of the section. A clayey gravel is present at a similar depth in OW3 that is also part of this unit, however the presence of the clay matrix is likely to diminish the hydraulic conductivity of the unit. The cross section shows a clay unit at OW-3 overlying this clayey gravel interval. The sand thickness increases, and interbedded clays are absent at boring H-11, near Washington Street. The presence of possible multiple channel units with intervening clays appears to have localized transport of the VOC plume at the site to the area centered around OW-8.

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Figure 3-24 provides a three-dimensional view of the distribution of lithologies at the site. A column representing each boring location is color-coded to indicate the relative permeability of lithologies encountered at each location. A three-tiered classification system was used on this figure, with the yellow zones indicating intervals with the highest relative hydraulic conductivity, orange indicating intermediate values and blue indicating intervals with the lowest relative hydraulic conductivity. The highest relative hydraulic conductivity class was assigned to deposits that consisted primarily of sand or gravel, with limited silt and clay content. The intermediate hydraulic conductivity class was assigned to lithologies that included primarily sand or gravel, but with significant silt or clay, which will lower the hydraulic conductivity. The lowest hydraulic conductivity class was assigned to intervals that were primarily silt or clay. This figure illustrates the limited areal extent of the upper aquifer east of Putnam near the presumed source area. Boring logs along Putnam Street and downgradient show significant high and intermediate hydraulic conductivity material is present that pinches out to the east of Putnam Street. The upper aquifer zone comprises a channel-like feature extending from near Putnam Street, toward the

west. Information on the deeper aquifer is more limited, with only three wells extending to a sufficient depth. Based on this limited information, a similar trend occurs near the Omega site east of Putnam Street, where sandy intervals are very limited.

Regional hydrogeologic information is inconclusive on the presence or absence of major regional named aquifers in this portion of the Whittier Area. A cross-section about 1.5 miles south of the site is presented in Bulletin 104 (DWR, 1961) that suggests that the uppermost aquifers present are the Gage and Jefferson Aquifers. The upper aquifer at the site may represent the Gage aquifer, while the lower aquifer is potentially the Jefferson aquifer.

3.2 Water Level and Groundwater Elevation Results

All Omega wells were surveyed and groundwater elevation calculated at each location using the water level measurements for each well. Groundwater elevation results are summarized in Table 3-2. As indicated on the groundwater elevation contour maps (Figures 3-2 through 3-18), the direction of groundwater flow in the upper aquifer was consistently towards the southwest during all 17 water level monitoring events. Insufficient water level data are available in the lower aquifer to define the groundwater flow direction. As directed by USEPA, OSVOG (Omega Small Volume Group), is currently proposing to install additional shallow and deep wells in the area downgradient of the Site. These wells will allow better definition of flow pathways in both the shallow and deeper aquifer zones.

There is a noticeable change in hydraulic gradient in the vicinity of Washington Boulevard and the OW-4 monitoring well cluster, which corresponds to the observed transition from finer-grained subsurface lithology in the area northeast of Washington Boulevard to coarser-grained subsurface lithology in the area southwest of Washington Boulevard. During the August 2004 sampling event, hydraulic gradient upgradient of cluster well OW-4 was approximately 0.01 ft/ft, and downgradient of cluster well OW-4 it was approximately 0.003 ft/ft. A similar trend was observed during the August 2001 sampling event, with a hydraulic gradient of approximately 0.01 ft/ft upgradient of cluster well OW4 and 0.002 ft/ft downgradient of cluster well OW-4.

As indicated by review of the hydrographs provided in Appendix G, water levels have generally been declining throughout most of the monitored period (May 2001 through August 2004). During the monthly monitoring that occurred during mid-2001 to mid-2002, water levels were generally slightly higher during spring and summer months, and slightly lower during fall and winter months.

As observed at the three locations where shallow and deeper well pairs (OW1, OW4 and OW8) are present, groundwater elevations in the deeper wells were consistently deeper than the elevations observed at the shallow wells at those locations. Appendix G presents each of these paired wells on the same figure to allow comparisons between the well pairs. Also, as water levels have dropped over time in wells OW1/

OW1b and OW4a/ OW4b, the differences in head between the monitored zones have increased at both locations. For example, at OW1/OW1b during May 2001, the head difference between the two zones was 3.43 feet. During the August 2004 sampling event, the head difference between the two wells was 9.28 feet. The well pair at OW4a/OW4b exhibited a similar trend, with a head difference of 3.76 feet in May 2001 and 8.99 feet in August 2004. The difference in head at location OW8/OW8b during August 2004 was 17.4 feet. The August 2004 sampling event was the initial sampling of newly-installed well OW8b. Subsequent sampling at OW8/OW8b will allow for additional evaluation of head differences at that location. The most recent measurements, taken in February, 2005, show an increase in water level in the deeper zone monitoring wells that decreased the head difference between the upper and lower aquifers. The vertical gradient remained downward.

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This head difference suggests that significant hydraulic separation exists between the shallow and deeper screened zones. The head differences also indicate a downward hydraulic gradient at these locations, suggesting that there is the potential for contaminants to migrate downward towards the deeper zone. Water quality results from the three well pair locations support the assumption that hydraulic separation between the two zones limits downward vertical migration.

3.3 Quarterly and Semi-Annual Groundwater Sampling Analytical Results

As discussed previously, water quality samples were collected quarterly from all Omega wells for one year starting mid-May 2001 and ending mid-February 2002. In addition, samples were collected on a semi-annual basis starting in mid-August 2002. Semi-annual sampling is currently on-going. Analytical results for all detected compounds (laboratory and field) are summarized in Tables 3-3 through 3-9.

The following discussion of groundwater sample analytical results is limited to samples collected from wells in the Phase 1a area (OW1, OW1b, OW2, OW3, OW8, and OW8b), along Washington Boulevard (OW4a and OW4b), and the well directly upgradient from the Omega facility (OW7). Screened intervals for each well are indicated on the majority of the analytical summary tables. The results of routine groundwater sampling performed since May 2001 are discussed below.

Time-series plots for six selected compounds (PCE, TCE, Freon 11, Freon 113, 1,1-DCE, and 1,4-dioxane) were prepared to illustrate concentration changes over time. Two sets of graphs were prepared, with one set of graphs showing each individual compound in all eight wells, and the second set illustrating the concentrations over time of the six compounds on a per well basis. Both sets of graphs are provided in Appendix G.

3.3.1 Chlorinated VOCs

Chlorinated VOCs have been detected more frequently and at elevated concentrations in the Phase 1a area, therefore, they are the primary compounds of concern at the Site.

The following discussion regarding chlorinated VOCs is based on well location with respect to distance from the assumed on-site source area, and depth (see Table 3-1 for well construction information and screened intervals). As shown on Figure 3-1, wells OW1 and OW1b are located at or in close proximity to the Site and are considered source area wells. Putnam Street wells OW2, OW3, OW8, and OW8b are located a short distance (e.g., approximately 300 feet) downgradient from the Site. As discussed previously, these six wells are located within the Phase 1a study area. Wells OW4a and OW4b are located on Washington Boulevard approximately 1,000 feet downgradient from the Site. At the three locations where a deeper well is paired with a water table well (OW1 and OW1b, OW4a and OW4b, and OW8 and OW8b), the vertical extent of chlorinated VOCs is discussed.

Source Area Wells OW1 and OW1b

Well OW1 is a water table well (screened from 62.5 to 77.5 feet bgs) located on-site and is considered a source area well. Well OW1b (screened from 110 to 120 feet bgs) is a deeper well located on the adjacent Terra Pave property, and paired with well OW1 provides information on the vertical extent of chlorinated VOCs in the general area of the assumed source.

The compound detected at the highest concentration in well OW1 during the quarterly and semi-annual sampling events was tetrachloroethene (PCE), which was detected at concentrations ranging from 30,000 micrograms per liter (ug/l) in February 2002 to 150,000 ug/l in February 2004 and August 2004 (based on the duplicate sample result). TCE was also detected in well OW1 at concentrations ranging from 12,000 ug/l (June 1996 and August 2004) to 2,100 ug/l (July 1999).

Other chlorinated VOCs detected at elevated concentrations included 1,1,1-trichloroethane (1,1,1-TCA) at a maximum concentration of 12,000 ug/l in August 2004 (based on duplicate sample result); 1,1-dichloroethene (1,1-DCE) at a maximum concentration of 2,700 ug/l in May 2001; chloroform (CFM) at a maximum concentration of 500 ug/l in May 2001 and February 2003; and methylene chloride (MC) at a maximum concentration of 490 ug/l in May 2001. During the previous four semi-annual sampling events, MC concentrations in the well have ranged from 72 to 41 ug/l. Freon concentrations in well OW1 appear to be declining over time, from a high of 1,400 ug/l (Freon 113) during August and November 2001 to 150 ug/l in August 2004 (based on the duplicate sample result). Freon 11 has exhibited a similar trend over the same time period.

Chlorinated VOCs were generally not detected in near-site deeper well OW1b. The primary exception was PCE, which was detected at concentrations several orders-of-magnitude lower in well OW1b compared to well OW1. The concentration of PCE in well OW1b ranged from 110 ug/L in August 2003 to 28 ug/l in February 2002. These data indicate that chlorinated VOC concentrations decline with increased depth and appear to be of limited vertical extent.

Putnam Street Wells OW2, OW3, OW8, and OW8b

Chlorinated VOCs were detected in water table wells OW2, OW3, OW8, and OW8b located approximately 300 feet downgradient from the Site along Putnam Street. Based on evaluation of the analytical results, the following general observations were made regarding the concentrations of chlorinated VOCs in the four wells.

Chlorinated VOC concentrations in the three Putnam Street wells were less than those observed in the on-site source area well (OW1). For example, PCE was detected at a concentration of 13,000 ug/l in well OW8 in February 2003, compared to a concentration of 100,000 ug/l detected in on-site source area well OW1 during February 2003.

The concentrations observed in wells OW2 and OW3 were generally comparable to each other. PCE concentrations in wells OW2 and OW3 during quarterly and semi-annual sampling ranged from 610 to 2,800 ug/l and from 200 to 3,200 ug/l (in the duplicate sample collected February 2004), respectively. As indicated on the time-series plot for well OW2, the concentration of PCE has been steadily increasing in the well since August 2002.

TCE concentrations in wells OW2 and OW3 ranged from 110 to 300 ug/l and 160 to 290 ug/l (in the duplicate sample collected February 2004), respectively. Maximum concentrations of other chlorinated VOCs detected in well OW2 were 1,000 ug/l 1,1-DCE; 1,600 ug/l Freon 113; and 390 ug/l Freon 11. Maximum concentrations of other chlorinated VOCs detected in well OW3 were 1,700 ug/l 1,1-DCE; 530 ug/l Freon 113; and 380 ug/l Freon 11. Freon concentrations in the two wells appear to be slowly declining over time.

In comparison, the concentrations of chlorinated VOCs detected in well OW8 were generally higher than the concentrations detected in wells OW2 and OW3. This suggests that the area transmitting most of the contaminant mass is relatively narrow and centered in the area of OW-8. Maximum concentrations of PCE, TCE, 1,1-DCE, Freon 113 and Freon 11 detected in groundwater samples collected from well OW8 were 36,000 ug/l; 2,200 ug/l; 2,600 ug/l; 2,800 ug/l and 1,000 ug/l, respectively. In addition, MC and CFM were detected at maximum concentrations of 6,500 ug/l and 2,000 ug/l, respectively, in groundwater samples collected from well OW8. By comparison, MC and CFM were detected either at low concentrations or were not detected in samples collected from wells OW2 and OW3.

At location OW8, MC and CFM concentrations increased from the initial quarterly sampling event in March 2002 (36 and 390 ug/l, respectively) to the most recent semi-annual sampling event in August 2004 (1,700 and 6,300 ug/l, respectively). The concentration of MC detected in well OW8 during the February 2003 sampling event (930 ug/l) was higher than the concentration (72 ug/l) detected in on-site source area well OW1. The concentrations of Freon 113 and Freon 11 were also higher in well OW8 in comparison to the concentrations reported for well OW1. This trend was also observed during all subsequent semi-annual sampling events.

Newly-installed deeper well OW8b was sampled for the first time during the August 2004 sampling event. A low concentration of 2.1 ug/l PCE was detected in the well, and all other VOCs and 1,4-dioxane were non-detect. As discussed in Section 3.3.4, elevated concentrations of several VOCs and 1,4-dioxane were detected in groundwater samples collected from the shallow well (OW8) at this location. The observed water quality differences between wells OW8 and OW8b provide additional support for a significant confining zone that limits flow between these zones.

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Washington Boulevard Wells OW4a and OW4b

Chlorinated VOCs were detected in Washington Boulevard water table well OW4a located approximately 1,000 feet downgradient from the Site. Concentrations were generally several orders of magnitude less than concentrations observed in the on-site source area well (OW1), and several times less than concentrations observed in Putnam Street wells OW2 and OW3. Chlorinated VOC concentrations, therefore, were observed to decrease with increased distance downgradient from the source area.

The compound MC, which was detected at elevated concentrations in the groundwater samples collected from well OW8, was not detected in the samples collected from well OW4a at a detection limit of 5 ug/l. During the most recent sampling event in August 2004, an estimated concentration (i.e., below the reporting limit) of 1.1 ug/l was detected in the well. In addition, the concentration of CFM was several orders of magnitude lower in the samples collected from well OW4a in comparison with the concentration detected in samples collected from well OW8.

Low concentrations of chlorinated VOCs (e.g., 1.2 to 41 ug/l PCE) were generally detected in groundwater samples collected from deeper well OW4b during the quarterly and semi-annual sampling events. As discussed previously, well OW4b is located adjacent to well OW4a. For reference, well OW4a is screened from 49.8 feet to 69.8 bgs, with well OW4b screened from 112 to 122.3 feet bgs. During the two semi-annual sampling events in August 2002 and February 2003, PCE was detected at increased concentrations of 12 and 41 ug/l, respectively. During the August 2003 through August 2004 semi-annual sampling events, PCE decreased to 1.6 ug/l in well OW4b.

In addition, several additional compounds (TCE, 1,1-DCE, Freon 113 and Freon 11) were also detected in groundwater samples collected from well OW4b. As was observed at the source area well pair location (OW1/OW1b), the data for the downgradient well pair (OW4a/OW4b) demonstrate that chlorinated VOC concentrations decline with increased depth and appear to be of limited vertical extent.

Upgradient Well OW7

Several chlorinated VOCs were detected at low concentrations at the upgradient well (OW7) location. Maximum concentrations of 20 ug/l PCE, 2 ug/l TCE, 63 ug/l Freon 113, and 54 ug/l Freon 11 were detected in the upgradient well. Land use upgradient from OW7 is primarily commercial and residential. The source of this observed

contamination is unknown, however, it is likely indicative of regional contamination in areas upgradient of the Site.

3.3.2 Aromatic VOCs

Several aromatic organics have historically been detected at relatively low concentrations in on-site source area well OW1 (see Table 3-4). During the most recent August 2004 semi-annual sampling event, aromatic compounds were detected at concentrations comparable to the prior sampling events. During the August 2004 sampling event, the following aromatics were detected in groundwater samples collected from on-site source area well OW1: benzene at 7 ug/l, toluene at 9.6 ug/l, ethylbenzene at 3.1 ug/l, total xylenes at 0.55 ug/l, and isopropylbenzene at 1.5 ug/l. Historically, with the exception of sporadic low-level detections close to or below the reporting limit, aromatic organics have not been detected in deeper well OW1b. With one minor exception (acetone at an estimated [i.e., below the reporting limit] concentration of 6.1 ug/l), they were not detected during the August 2004 sampling event.

Aromatic organics have also generally not been detected in groundwater samples collected from Putnam Street wells OW2 and OW3, Washington Boulevard well OW4a, and upgradient well OW7. Low levels of benzene (ranging from 0.79 to 1.8 ug/l) were detected in well OW4b during the August 2002 and February 2003 semi-annual sampling events, respectively. Acetone was routinely detected in well OW4b during groundwater sampling events prior to February 2004, at concentrations ranging from 28 to 1,500 ug/l. In addition, 2-propanol was also detected in the well prior to August 2002 at concentrations ranging from 350 to 940 ug/l.

Benzene, toluene, and acetone have also been detected in groundwater samples collected from well OW8 during quarterly and semi-annual sampling events. Benzene was detected at a concentration of 5.3 ug/l during the August 2002 semi-annual sampling event. Toluene concentrations during semi-annual sampling events ranged from 1.9 ug/l (March 2002) to 340 ug/l (August 2004), and acetone concentrations ranged from 41 ug/l (March 2002) to 7,400 ug/l (August 2004). An estimated concentration (i.e., below the reporting limit) of acetone was detected at a concentration of 5.7 ug/l in deeper well OW8b during its initial August 2004 sampling event.

Acetone concentrations in deeper well OW4b have declined from a high of 1,500 ug/l in November 2001 to below the reporting limit (8.4 ug/l in February 2004 and 5.2 ug/l in August 2004). The detection of acetone in well OW4b is believed to be a result of cross-contamination from coatings used in the manufacture of bentonite pellets at the time the well was installed. This problem was observed at many other sites where bentonite pellets have been used for well construction. Corrective action has since been taken by the manufacturer to resolve this issue. Acetone has been consistently detected at elevated concentrations only at location OW8. Uncoated bentonite pellets were used during the construction of well OW8, therefore, the acetone detections in shallow well OW8 are likely derived from the Site or other unknown sources.

3.3.3 Semi-VOCs, Pesticides, and Metals

Semi-VOCs and pesticides were analyzed for and not detected at locations OW1 and OW1b during all four quarterly sampling events (see Table 3-5). Total and dissolved metals were also analyzed at these two well locations and were generally found at background concentrations during all four quarterly sampling events (see Table 3-6). Based on these results, sampling and analysis for these parameters was discontinued at the start of semi-annual sampling.

3.3.4 Emerging Compounds

During the February 2003 semi-annual sampling event, additional analysis for three emerging compounds (hexavalent chromium, perchlorate, and 1,4-dioxane) at selected well locations was included in the analytical suite. Perchlorate was also analyzed in wells OW1 and OW1b during the four quarterly sampling events. Analysis for 1,4-dioxane has also been performed at all well locations since the November 2001 quarterly sampling event. Emerging compounds results are summarized in Table 3-7.

Perchlorate was detected in only one well, OW4b, at a concentration of 9.4 ug/l. Hexavalent chromium was detected in wells OW2, OW3, OW4a and OW8 at concentrations of 3.1, 5.4, 12 and 1.1 ug/l, respectively, during the February 2003 semi-annual sampling event.

The compound 1,4-dioxane was detected at high concentrations in groundwater samples collected from on-site well OW1, and ranged from 3,300 ug/l (estimated) during the November 2001 sampling event to 52,000 ug/l during the February 2003 semi-annual sampling event. The concentrations detected in deeper well OW1b were several orders of magnitude less, and ranged from 14 ug/l in August 2004 to 60 ug/l in August 2002.

1,4-dioxane was also detected in groundwater samples collected from well OW8 during the quarterly and semi-annual sampling events. Concentrations declined steadily from 1,000 ug/l in March 2002 to 180 ug/l in February 2003. Significantly increased concentrations were reported in samples collected from the well during test pumping at that location (2,600 ug/l during March 2003 and 2,700 ug/l during November 2003). The concentration declined to 210 ug/l in February 2004, and increased to a maximum of 5,300 ug/l during the August 2004 sampling event.

Relatively low concentrations of 1, 4-dioxane were detected in groundwater samples collected from wells OW2, OW3 and OW4a, with maximum detected concentrations of 12, 1.6, and 14 ug/l, respectively. 1,4-dioxane was not detected in deeper wells OW4b and OW8b. As was observed for chlorinated VOCs, 1,4-dioxane concentrations were observed to decline with increased depth and distance downgradient from the Site.

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3.3.5 Biodegradation/Natural Attenuation Parameters

As discussed previously, various biodegradation/natural attenuation parameters were analyzed during the most recent semi-annual sampling event in February 2003. Analysis was performed in the field using field test kits and direct reading instruments, and also by an off-site laboratory. Laboratory results are summarized in Table 3-8, with field results summarized in Table 3-9.

Laboratory Results

Nitrate concentrations ranged from 11 to 8.8 milligrams per liter (mg/l) in samples collected from the water table wells (OW1, OW2, OW3, OW4a, and OW8) to 2.7 mg/l in deeper well OW1b. Nitrate was not detected in deeper well OW4b. Nitrite was detected at a concentration of 1 mg/l at one well location (OW1b).

In accordance with the criteria specified in Section 2.2, samples for methane, ethane, and ethene analyses were collected from water table wells OW1 and OW8, and deeper well OW1b. Concentrations in well OW1 were 4.8 ug/l; 3,200 nanograms per liter (ng/l); and 1,400 ng/l, respectively. Concentrations in deeper well OW1b were 2,400 ug/l; 480 ng/l; and 1,500 ng/l, respectively. Concentrations in well OW8 were 4.7 ug/l; 36 ng/l; and 1,000 ng/l, respectively.

Field Results

As shown in Table 3-9, electrical conductivity measurements ranged from 1,140 micromhos per centimeter (umhos/cm) at well location OW1b to 1,676 umhos/cm at well location OW8. pH measurements ranged from 6.73 at well location OW1 to 7.30 at well location OW4b. Dissolved oxygen measurements for samples collected from source area wells OW1 and OW1b were less than 1 parts per million (ppm). Redox potentials were negative at locations OW1, OW1b, OW4b, and OW8. Carbon dioxide was detected at all sampled locations except for well OW4b. Ferrous iron was detected at well locations OW1, OW1b, OW3, and OW8. Sulfate concentrations ranged from 162.5 mg/l (OW1) to 475 mg/l (OW1b). Chloride concentrations ranged from 26.25 mg/l (OW3) to 72.5 mg/l (OW8).

3.4 Soil Sampling Analytical Results

A total of 33 soil samples for laboratory analysis were collected from borings GP1 through GP8 during the drilling program described in Section 2.3 of this document. Analytical reports are provided in Appendix D, with a summary of all detected compounds provided in Table 3-10. The MIP screening results are also provided in Appendix D.

PCE was detected most frequently and at elevated concentrations at all of the sampled locations. At location GP3A, PCE concentrations decreased from 3,200 ug/kg at a depth of 10 feet bgs to 130 ug/kg at a depth of 32 feet bgs. PCE then increased to reach a maximum concentration of 12,000 ug/kg at a depth of 65 feet bgs. TCE concentrations at location GP3A ranged from 6.9 ug/kg at a depth of 30 feet bgs to 190 ug/kg at a depth of 65 feet bgs. Two other chlorinated VOCs were also detected

at elevated levels in the boring, as follows: 1,1,1-TCA at a maximum concentration of 130 ug/kg at a depth of 65 feet bgs, and 1,2-dichloroethane (1,2-DCA) at a maximum concentration of 220 ug/kg at a depth of 45 feet bgs. Several other chlorinated VOCs (1,1,2-TCA; 1,1-DCA; and CFM) were also detected in the boring at concentrations less than 10 ug/kg.

1,4-dioxane concentrations at this location decreased in the interval from 10 to 32 feet bgs (from 10,000 to 300 ug/kg), and declined to non-detectable levels from 45 feet to the bottom of the boring at 85 feet bgs. It is likely that this former UST area was a source area for spills or leaks from the former UST. The increases in PCE, TCE, and 1,1,1-TCA noted above at 65 feet bgs are likely the result of contaminants migrating from contaminated groundwater to the capillary fringe during times of historical high water table conditions.

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3.5 Aquifer Testing

From March 10 through March 14, 2003, CDM conducted four single borehole pumping tests at wells OW2, OW3, OW4a, and 8. Each test was approximately four-hours in duration. CDM used an In-Situ Mini-Troll™ datalogger/sensor to monitor water levels at logarithmic intervals in the pumping well during the test activities. CDM also collected manual water level measurements prior to, during, and after the testing period in the pumping well and closest observation wells. During November 2003, longer-term constant rate pumping was performed at well OW8. The newly-installed piezometers and nearby wells were utilized as observation wells.

CDM metered the discharge during each test and collected totalizer readings at the beginning and end of the pumping period. Due to some flow adjustments made during testing, a constant discharge rate was difficult to maintain at the locations of OW2, OW3, and OW4a. Totalizer readings were used to estimate the average pumping rate for the entire test period. Therefore, the average pumping rate calculated from the totalizer readings may not reflect the true rate at any specific period during the test. As discussed previously in Section 2.1.2, groundwater samples were collected for laboratory analysis immediately prior to the termination of pumping at each tested well location. The analytical results of samples collected during aquifer testing are discussed below.

3.5.1 Water Quality Sampling and Analysis

As previously discussed, water quality samples for laboratory analysis were collected just prior to the termination of pumping at all well locations which were test pumped during March 2003 (OW2, OW3, OW4a, and OW8) and November 2003 (OW8).

VOC concentrations in samples collected from wells OW2, OW3, and OW4a during March 2003 were generally comparable to concentrations detected during the February 2003 semi-annual sampling event. Concentrations of PCE, TCE, 1,1-DCE, 1,1-DCA, 1,2-DCA, and CFM detected in samples collected from well OW8 were generally two to three times higher during March 2003 compared to February 2003.

1,1,1-TCA concentrations in well OW8 increased approximately an order of magnitude from February 2003 to March 2003. Freon 113 and Freon 11 concentrations in well OW8 were comparable during the two sampling events. The concentration of toluene in well OW8 was approximately 20 times higher during March 2003.

The concentration of 1,4-dioxane in the sample collected during March 2003 from well OW8 was 2,600 ug/l, an approximate order-of-magnitude increase compared to the February 2003 result of 240 ug/l. A duplicate sample collected from well OW8 also reported a 1,4-dioxane concentration of 2,600 ug/l. The concentrations of 1,4-dioxane in the other three test pumped wells (OW2, OW3 and OW4a) during March 2003 remained relatively low or non-detected, and were not observed to increase compared to the February 2003 results.

Similar concentration increases were also noted during the November 2003 sampling event which followed approximately 20 hours of pumping at well OW8. There are several possible reasons for the observed increases in well OW8 during the March and November 2003 sampling events. The higher levels were observed after well OW8 had been pumping at an increased rate, likely drawing from areas of higher mass closer to the source area on the site. During March 2003 aquifer testing, for example, well OW8 was pumped at approximately 10.4 gallons per minute (gpm) for 4 hours, with approximately 2,500 gallons of groundwater pumped from the well. During routine groundwater sampling one month earlier in February 2003, the well was purged at approximately 3 gpm for 40 minutes, with a total purge volume of 117 gallons. It is also possible that variations in sampling equipment could have had some effect on the sample. The sample collected immediately prior to the termination of aquifer testing was collected directly from the discharge line. The sample collected during routine groundwater sampling was collected using a disposable bailer lowered to the middle of the perforated section after the portable pump had been removed from the well. This is the standard USEPA-approved procedure which is utilized during routine groundwater sampling of Omega wells. In addition, as discussed below, well OW8 appears to be located within a higher-permeability channel-like deposit which may be more hydraulically connected to higher mass, upgradient areas than wells OW2 and OW3. Another explanation for the increased concentration is that a cross-gradient portion of the plume may have been tapped via a preferential groundwater flow pathway, such as the sand channel, due to changes in the flow field during the test. In addition, there was a lack of similar increase observed for other chlorinated VOCs (e.g., PCE and TCE). This suggests a possible difference between the transport and release mechanisms for 1,4-dioxane vs. PCE and TCE. Fate and transport mechanisms for these compounds are discussed in detail in Section 4.1.4.

3.5.2 Evaluation of Aquifer Parameters

CDM evaluated aquifer properties from the results of the four single borehole pumping tests and one multiwell aquifer performance test by analyzing the pumping test drawdown and recovery curves in accordance to the methods described in the CDM Aquifer Hydraulic Tests Standard Operating Procedure (SOP-FL-010)

(CDM, July 15, 1993). Table 3-11 summarizes the test results and aquifer properties estimated from the various analyses that were performed. A description of each of the aquifer properties and methods used to estimate the aquifer parameters are provided below.

Drilling logs and well construction details are included in Appendix A and described in Section 3.1. For the purpose of analyzing the pumping test data, CDM reviewed the well logs and water level data to estimate the saturated thickness of the aquifer at each well location. Based on this review it appears that although the aquifer is overlain by about 50 feet of silty clay at the site, it is not completely saturated and, therefore, the shallow groundwater is considered to occur under water table (unconfined) conditions.

Transmissivity represents the capacity of the full aquifer thickness to allow passage of water. It is estimated using pumping test drawdown and recovery measurements. CDM estimated transmissivity from the pumping test data using manual straight-line curve matching based on the Cooper-Jacob solution as outlined in SOP-FL-010 for the single borehole tests. Figures E-1 through E-4 show the time-recovery plots for each of the single borehole pumping tests and the straight-line curve used to estimate transmissivity based on the Cooper-Jacob method. The Theis equation and all derivations used (Cooper-Jacob, t/t') for analyzing the pumping tests are based on assumptions summarized in Driscoll (1986). The values estimated using the recovery data at the pumping well may be impacted by well losses and dewatering of the aquifer near the well.

Well OW2 was pumped at a rate of 2.3 gpm for a four hour period. The recovery curve shows the typical shape, with recovery to near the original level in a short period. The slope of the later portion of the recovery curve (small t/t' values) was used to estimate the transmissivity, which was 170 ft² /day. Well OW3 was tested at a rate of 1.3 gpm for four hours. This test could not be analyzed due to the short recovery period that was monitored. The sustained production rate suggests that the transmissivity is lower than that observed at OW2. Well OW4a was pumped at 10.3 gpm for four hours. The recovery was rapid and returned to the pre-pumping level, with a recovery curve shape conforming to the expected response. The slope on the later portion of the curve resulted in a transmissivity estimate of 2691 ft² /day. Well OW8 was pumped at 10.4 gpm for four hours. The recovery curve does not return to pre-pumping levels, with about 7 feet of drawdown at the end of the recovery period. The shape of the recovery curve was as expected, and yielded a transmissivity estimate of 1616 ft² /day. This estimate is considered uncertain due to the high remaining drawdown at the end of the test and is superseded by results from the subsequent multiple well test in this area.

A multi-well test was conducted by pumping OW8 and monitoring the response at wells OW1b, OW2, OW3, OW4a, OW7, and OW8, and piezometers PZ-1 and PZ-2. The water level plots are provided in Appendix E. Well OW8 is screened across the entire saturated thickness of the upper aquifer, in the area where a lower permeability

unit occurs within the aquifer. Groundwater occurs under water table conditions in this area, so an analytical method appropriate to unconfined conditions was chosen. The Neuman (1972) method of analysis for unconfined aquifers was selected as appropriate, since the wells are considered to fully penetrating the upper aquifer zone. Many of the monitored wells did not have significant drawdown and could not be analyzed in a quantitative manner. Wells OW4a and OW7 were not impacted by the test, since they are located far from the pumping well. Wells OW2 and OW3 showed a possible response to pumping, but the magnitude was too small for quantitative analysis. Well OW2 did not show any recovery after the pumping phase, suggesting that the water level decline observed during pumping may be coincidental. Well OW3 did show a small recovery after pumping, but the magnitude of the recovery was much lower than would be anticipated. Piezometers PZ-1 and PZ-2 showed good response to the test and were analyzed using the Neuman unconfined method cited above. Well OW1b was measured manually using a wireline probe. This well follows a trend similar to that observed at the pumping well, however, this appears to be coincidental and unrelated to the pumping test. Well OW1b is screened below the elevation of OW8 in a silt and clay zone and is 220 feet from well OW8. The magnitude of the apparent response is small (about 0.1 foot) and was determined from sparse manual measurements. Since this well is screened in very low hydraulic conductivity material that lies below the upper aquifer materials pumped at OW8, the response at this well, though uncertain, does not appear to be related to the testing at OW8. Water levels in wells OW1/OW1b will be monitored during future pumping in the Phase 1a area, in order to provide further information regarding a possible response at this location.

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Well PZ-1 is located 48 feet from OW8, and exhibited a maximum drawdown of 0.49 feet. The drawdown curve is provided on Figure E-5, along with the fitted curve and aquifer parameters associated with the curve. Calculations for the Neuman curve fits were facilitated using the commercial software package AquiferWin32. The analysis at PZ-1 resulted in an estimate of 563 ft²/day for transmissivity. Well PZ-2, located 53 feet from the pumping well, exhibited a maximum drawdown of 0.27 ft. Figure E-6 shows the drawdown and analysis for this well. The estimated transmissivity at PZ-2 was 810 ft²/day. Based on the thickness of productive sand intervals at these wells, the hydraulic conductivity of these sands is estimated to range from 50 to 100 ft/day, for purposes of estimating velocities in the aquifer, based on a saturated thickness of less than 10 feet for the productive units within the screen zone. Estimates of the specific yield were also determined during the test, and ranged from 0.09 to 0.2. The test was likely not long enough to obtain a reliable estimate of the specific yield. Wells PZ-1 and PZ-2 are located at similar distances from the pumping well, yet show significant differences in hydraulic properties, suggesting that local variation is significant on scales of less than 100 feet. This local scale variability introduces some uncertainty on estimates of hydraulic characteristics, since one of the assumptions in the Neuman method is uniform characteristics within the tested domain. As previously discussed, all pumped water was contained in a portable storage tank for disposal at an off-site facility. It was, therefore, not practical to conduct a longer-term pumping test.

Background water levels were monitored at wells OW1, OW1b, OW4a, OW4b, OW7 and OW8 in March and April, 2004. Hydrographs of relative water level fluctuation for each of these wells are provided in Appendix E. Wells in the upper aquifer (OW1, OW4a, OW8 and OW8) indicated falling water levels, while the deep zone wells showed rising water level trends. The magnitude of the daily fluctuations was very small.

3.6 Quality Assurance/Quality Control and Data Validation

A variety of Quality Assurance/Quality Control (QA/QC) samples (e.g., duplicates and equipment blanks) were collected during groundwater sampling. In addition, double or triple volume for laboratory QC samples (Matrix Spike/Matrix Spike Duplicate [MS/MSD]) were also collected and submitted to the laboratory. QA/QC sample results are included in the analytical summary tables.

The laboratory provided both hard copy and electronic results. Electronic results were imported directly into the project's Access database. All laboratory analytical data generated during the groundwater monitoring events were reviewed and evaluated to ensure that they were usable and met the project objectives prior to incorporating the data into the database. To this extent, USEPA's Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review (USEPA, 1999 and 2002, respectively) were used in conjunction with the project work plan to assess overall analytical data quality.

Level IV data packets (CLP-Like) were requested for one sample group per groundwater monitoring event, which was subjected to formal data validation. A sample group consists of all samples collected on a single day and submitted to the analytical laboratory on an individual COC. Although a target validation frequency of 10 percent was proposed in the project work plan, the actual percentage was much greater and ranged from approximately 30 percent to nearly 70 percent depending on the analysis validated. The sample group selected for validation was based on the number and type of samples collected and the type of analyses requested. In other words, the sample group selected for validation contained the largest number of samples collected in one day and submitted for analysis of the greatest variety of parameters in order to provide the most comprehensive level of validation. A sample matrix is provided as Table H-1 (included with Appendix H), which summarizes the number and types of samples collected each day and identifies the samples that were formally validated. Data validation reports are included in Appendix H.

All other laboratory data that were not subject to formal validation were reviewed for data usability and for inclusion and frequency of the necessary QC supporting information. Supporting QC documentation that were evaluated for each analytical report included the following major items:

- sample holding times

- method blanks
- matrix spike/ matrix spike duplicate (MS/MSD) recoveries
- relative percent difference (RPD) between MS and MSD
- laboratory control sample (LCS) recoveries
- surrogate recoveries (organic analyses)
- field quality control sample results

Prior to incorporating the Omega analytical data into the database, the electronic data were checked for accuracy against the hard copy analytical reports. Standard procedure includes contacting the laboratory in the event that discrepancies are discovered, resolving and correcting discrepancies, and reissuing the analytical reports, as necessary. Data validation reports for seven Level IV data packets (November 2001, February 2002, August 2002, February 2003, August 2003, February 2004, and August 2004) are presented in Appendix H. No significant QC issues were noted during the review process; therefore, with two minor exceptions, all data can be used for project purposes without qualification. The exceptions are the 1,4-dioxane result (1.6 ug/l) for well OW3 during August 2003, and the MC result (1.2 ug/l) for well OW1b during August 2004. Both results have been qualified in the database (and shown on the analytical summary tables) as "UB", indicating that the result was not detected due to the detection of the analyte in the laboratory method blank.

Section 4

Conclusions and Recommendations

Based on evaluation of the historical and recently-acquired lithologic, water level, analytical, and aquifer testing data, the following conclusions and recommendations are provided.

4.1 Conclusions

Conclusions regarding groundwater flow direction, groundwater sampling results, and fate and transport of compounds detected in groundwater in the Phase 1a area are presented below.

4.1.1 Groundwater Flow Direction and Gradients

Monthly and semi-annual water level monitoring performed to date indicates a consistent groundwater flow direction towards the southwest in the water table zone (upper aquifer). Hydraulic gradients upgradient of cluster well OW4 were consistently steeper than the gradients observed downgradient of the well cluster (0.01 ft/ft vs. 0.002 ft/ft and 0.003 ft/ft). In addition, water levels have generally been declining throughout most of the monitored period. The groundwater flow direction and hydraulic gradient has been relatively consistent in the upper zone over the monitoring period. Also, as water levels have dropped over time in wells OW1/OW1b and OW4a/OW4b, the differences in head between the monitored zones have increased at both locations. During the most recent August 2004 sampling event, the head difference between the OW1/OW1b well pair was 9.28 feet, with a head difference of 8.99 feet observed at the location of well pair OW4a/OW4b. The difference in head at location OW8/OW8b during August 2004 was 17.4 feet.

4.1.2 Groundwater Sampling Results

Chlorinated VOCs and 1,4-dioxane have been detected more frequently and at elevated concentrations in the Phase 1a area, therefore, they are the primary compounds of concern. Additional detected chemicals will also be considered compounds of concern, as necessary, with respect to their potential to impact the groundwater treatment system and disposition of the treated groundwater.

Chlorinated VOCs were detected in all Phase 1a area wells, including the upgradient background well. Therefore, it is likely that the shallow groundwater underlying the entire Phase 1 area has been impacted by chlorinated VOCs. Historical aerial photographic analysis performed by USEPA in 2000 indicated that there were a large number of possible hazardous waste release sites in the immediate vicinity of the Omega Site and in the area immediately downgradient from the Site. It is likely, therefore, that the plume downgradient of the Omega Site contains contaminants derived from other currently unknown sources. Due to the industrialized nature of the area, the likelihood of contribution from these unknown sources increases with distance downgradient from the Omega Site.

Based on observations at two locations where a water table and deeper well pair are present (OW1 and OW1b, and OW4a and OW4b), chlorinated VOC concentrations were observed to decline with depth and appear to be of limited vertical extent. As previously discussed, OSVOG is currently proposing to install additional shallow and deep wells in the area downgradient of the Site. These wells will allow better definition of contaminant concentrations and flow pathways in both the upper and lower aquifer zones. Concentrations were also observed to decline with increased distance downgradient from the Site. Aromatic organics, semi-VOAs, pesticides, and metals were detected sporadically and at relatively low concentrations in groundwater samples collected from the Phase 1a area wells, therefore, they are not considered compounds of concern.

Based on evaluation of the lithologic, aquifer testing, and groundwater sampling results, there appears to be a higher-permeability channel deposit immediately downgradient of the Site in the vicinity of well OW8 on Putnam Street. Relatively higher (compared to well OW2 to the north and well OW3 to the south) VOC and 1,4-dioxane concentrations were also detected in this area. Samples from the current monitoring program and early site investigations indicate that migration of CVOCs from the site occurs primarily within the noted higher permeability deposits that extend from approximately the location of temporary probe H-7 on the north to H-11, near the intersection of Washington and Putnam. Based on observed concentrations, most mass is transmitted through the center of this feature, near the location of OW-8. The extent of contamination has been sufficiently defined for purposes of remedy design for groundwater containment in the vicinity of Putnam Street. Additional design-level data will likely be needed as remedial design proceeds. The remedy may also be modified, as needed, based on the findings of the additional well installations and sampling to be performed by OSVOG.

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4.1.3 Soil Sampling Results

Soil sampling results indicate the presence of a contaminant source at the location of the former UST. Soil contamination was also observed associated with contaminated groundwater and the capillary fringe.

4.1.4 Fate and Transport

Groundwater sampling results indicate that the highest contaminant concentrations are associated with the former source area locations that are upgradient of Putnam Street, and that this contamination is predominantly limited to the shallower portions of the aquifer. These contaminants include various chloroethene parent compounds (PCE and TCE) and their primary daughter product pathways (cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride [VC]); chloroethane parent compounds (PCA, 1,1,1-TCA, and 1,1,2-TCA) and their daughter products (1,1-DCA, 1,2-DCA, and 1,1-DCE [abiotic hydrolysis of 1,1,1-TCA]); chloromethanes (CTC, CFM, and MC), and freons. The compound 1,4-dioxane was also found at elevated concentrations on-site at the location of boring GP3A, and is included in the below discussion.

The highest VOC concentrations are found within the shallow groundwater plume as evidenced by data from well OW1 (screened from 62.5 to 77.5 feet bgs) during the August 2004 semi-annual sampling event. In particular, the data indicate elevated concentrations of the parent-compounds PCE (150,000 ug/l) and 1,1,1-TCA (12,000 ug/l), with TCE (3,500 ug/l) and 1,1-DCE (2,000 ug/l) present at substantially lower concentrations and likely as biotransformation daughter-products, respectively. The concentration of PCE detected at monitoring well OW1 (150,000 ug/l) represents 75 percent of the aqueous solubility of PCE (200,000 ug/l) and therefore provides strong evidence for the presence of a dense non-aqueous phase liquid (DNAPL) within this area of the Site. Conversely, groundwater data from monitoring well OW1b (screened from 110 to 120 feet bgs), which is screened in the deeper groundwater plume, during the August 2004 semi-annual sampling event indicate only minimal VOC detections at this deeper interval (PCE concentration of 87 ug/l; TCE concentration of 2.8 ug/l; and 1,1-DCE concentration of 2.2 ug/l), and aquifer characteristics that limit the vertical migration of contamination in this area.

Although the site data collected at monitoring well OW1 provide strong evidence for the presence of DNAPL, assessing the fate and transport and hence the potential mobility of DNAPL is complex. Such an evaluation is particularly complex for the Omega site since DNAPL is likely to exist in three or four separate phases: (1) air phase, (2) solid phase, (3) immiscible phase, and potentially (4) water phase (i.e., dissolved in the event that the DNAPL reaches the water table). Evaluation of fate and transport at the site is further complicated by the likelihood that releases occurred during different, but unidentified, time periods. A release of DNAPL at the site would result in vertical migration of the DNAPL driven by soil capillarity as well as gravity. Capillary pressure is a measure of the tendency of a porous medium to suck in the wetting fluid phase, or to repel the non-wetting phase. In general, the capillary force increases in the following order: sand, silt, and clay (EPA, 1991). In unsaturated zone environments, DNAPL would generally serve as the wetting phase while air would serve as the non-wetting phase.

Correspondingly, unsaturated zone soils tend to serve as a significant "sink" for DNAPL. If the DNAPL release were relatively small, a point would be reached at which the DNAPL would no longer hold together as a continuous phase; rather, it would be separated under capillary forces as it is sucked into adjacent pore space where it would persist as isolated residual globules. In larger DNAPL releases, sufficient DNAPL may be released to reach the capillary fringe and/or water table. At the capillary fringe, water would be the wetting fluid and the DNAPL would serve as the non-wetting fluid. As such, the capillary fringe would obstruct the entry of the DNAPL into the saturated zone until sufficient volume of DNAPL has accumulated and the "DNAPL pressure head" exceeds the water capillary pressure at the capillary fringe (i.e., entry pressure). This phenomenon often results in an accumulation of DNAPL at the capillary fringe. The fraction of the hydrocarbon that is retained by the capillary forces in the porous media is referred to as residual saturation and may be quite significant in the fine-grained materials encountered at the site.

Due to the large depths at which water is encountered at the site (i.e., approximately 75 feet in the vicinity of OW1) and the predominance of fine-grained silts and clays in the subsurface, it is likely that a significant fraction of any DNAPL release at the site would be bound up in the unsaturated zone soils. While it is possible that DNAPL may have reached the water table, such an occurrence is unlikely (although not infeasible) since the source release volumes would have to be quite extensive to penetrate the thick unsaturated zone. Furthermore, groundwater data collected at OW1 indicate significant variability in PCE and TCE concentrations since 1996, which suggests that the VOC concentrations in groundwater are more likely to be controlled by leaching of contamination from the unsaturated zone (i.e., through DNAPL/water interactions and vapor/water interactions) rather than by dissolution from DNAPL within the saturated zone. For vadose zone environments, EPA considers DNAPL components adsorbed onto soil as immobile, whereas the mobile components are the soluble and volatile components of the DNAPL in the water and air, respectively (EPA, 1991).

Groundwater data collected from monitoring wells located downgradient of the source areas indicate a trend towards decreasing total VOC concentrations within the shallow groundwater plume, with increasing fractions of daughter products relative to the parent compounds along a defined contaminant flow path. To facilitate the analysis of VOC trends, two subsets of contaminants (chloroethenes and chloroethanes) and their degradation daughter products were identified. Monitoring wells OW1, OW8, and OW4A are located along a general hydraulic flow path in the shallow hydrologic zone, and this group of wells was used to evaluate the contaminant transport trends. Well OW5, which is located downgradient from Washington Boulevard wells OW4a and OW4b, is also included in this evaluation. VOC concentrations within both subsets were converted to units of molar concentration by dividing each chemical concentration by its respective molecular weight. For those chemicals below the reporting limit, a value equivalent to one half of the reporting limit was applied. The results of this analysis are presented in Table F-1 and Figures F-1 and F-2 in Appendix F.

The summation of chloroethenes along the defined flow path, along with the ratio of sequential dechlorination daughter products are depicted in the table. As shown in the table, the total molar concentration of chloroethenes decreases along the flow path from 931.2 umoles/L (OW1) to 0.5 umoles/L (OW4A), with a subsequent increase to 13.4 umoles/L at OW5. These data suggest an attenuation of contaminant mass along this flow path with an increase of mass at the furthest downgradient well (OW-5).

The apparent decrease in contaminant concentrations along the defined flow path provides supporting evidence of contaminant attenuation with distance traveled from the source area, whereas the increase in contaminant mass measured at OW-5 may be attributed to commingling groundwater contaminant plumes from more than one source. Furthermore, the ratio of PCE/TCE and TCE/cis-1,2-DCE decrease along this flow path suggesting limited, active biotransformation of parent compounds to daughter products may be occurring along the defined flow path. It is important to

note, however, that these conclusions are preliminary because they assume that the monitoring well network is hydraulically connected along the full length of the groundwater plume and that the network of monitoring wells provides a complete and accurate depiction of the contaminant travel path; the validity of these conclusions are weakened by the potential for tortuous flow paths and the presence of sand channels that may act as preferential contaminant flow paths.

1,4-dioxane, which is a fairly conservative contaminant (i.e., it does not sorb strongly to soils or readily biodegrade), occurs at elevated concentrations in groundwater near the Omega site; however, contaminant concentrations decrease substantially at the downgradient monitoring wells along the defined flow path. Concentrations of 1,4-dioxane at monitoring wells OW1 (6,300 ug/l) and OW8 (5,300 ug/l) support the conclusion that this contaminant is fairly conservative and its transport is accurately reflected by these two monitoring wells. However, concentrations of this same contaminant are substantially depleted at OW4A (1.8 ug/l) and OW5 (85 ug/l), suggesting that 1,4-dioxane has not had sufficient time to transport to the downgradient regions of the groundwater plume, or that these downgradient monitoring wells may not accurately depict the contaminant flow path from upgradient monitoring wells.

While both potential scenarios are feasible, an evaluation of the Freon 11 and Freon 113 data tend to support the former conclusion that 1,4-dioxane has not had sufficient time to transport downgradient. Specifically, Freon 11 and Freon 113 are fairly conservative contaminants and therefore the observed attenuation for these contaminants along the defined flow-path (i.e., due to natural attenuation processes, or errors introduced by the monitoring well network) should be similar to that of 1,4-dioxane. Concentrations of Freon 11 and Freon 113 at monitoring well OW4A (100 and 230 ug/l, respectively) are approximately 8 to 10 times less than observed at OW8 (800 and 2,200 ug/l, respectively). In contrast, the concentration of 1,4-dioxane at OW4A (1.8 ug/l) is approximately 650 times lower than observed at OW8 (5,300 ug/l). This discrepancy in apparent attenuation provides supporting evidence that the leading edge of the 1,4-dioxane groundwater plume may be shorter in length than other contaminant at the site; however, this conclusion is complicated by the presence of tortuous flow-paths as well as other site complexities.

The attenuation of chloroethane contaminants and their daughter products with distance traveled along the defined flow path in the shallow groundwater plume are presented in Table F-1. Similar analyses for the other subsets of contaminants were not performed due to the frequency of values below the reporting limits. The transient spike in the 1,1,2-TCA/1,2-DCA ratio is the result of concentrations below the reporting limits for both chemicals.

Estimates of the advective groundwater transport and contaminant migration velocities (V_A and V_C , respectively) are presented in Table F-2. Due to unique hydrogeologic properties encountered in the shallow hydrologic zone, the defined flow path from monitoring wells OW-1 to OW-5 is segregated into three "Segments"

for the purposes of this evaluation. The area between monitoring wells OW-1 and OW-8 is defined as Segment 1; the area between monitoring wells OW-8 and OW-4B is defined as Segment 2; and the area between monitoring wells OW-4B and OW-5 is defined as Segment 3. Estimates of V_A and V_C are presented separately for three "Segments" along the defined flow path, and the minimum and maximum transport times for groundwater and contaminants to travel along each individual Segment are presented in Table F-2. The minimum transport times for groundwater and contaminants to travel along the full length of the defined flow path (i.e., Segments 1 through 3) are 12.0 and 22.5 years, respectively; whereas the maximum transport times along this same flow path are 22.1 and 41.6 years, respectively. These estimates of potential transport times are generally consistent with available information on the historical operations at the site.

Despite the active dechlorination processes inferred from the above analyses, the dechlorination of the parent chloroethene and chloroethane contaminants appears to stall at intermediate biotransformation daughter products. This conclusion is supported by the relative abundance of the parent contaminants compared to their daughter products at all monitoring wells along the defined flow path. Under the proper groundwater environments, PCE may be sequentially biotransformed to TCE, cis-1,2-DCE, VC, and ethene/ethane, which are the terminal dechlorination products under reduced groundwater environments. Similarly, the TCA isomers may be sequentially biotransformed to DCA isomers, chloroethane, and ethane, while 1,1-DCE may be formed during abiotic hydrolysis of TCA. VOC data collected during August 2004 indicate that VC and chloroethane were not detected above the reporting limits (0.5 ug/L) at any of the OW-1 through OW-8 monitoring locations. Furthermore, the intermediate chloroethene and chloroethene daughter products (cis-1,2-DCE and DCA/1,1-DCE, respectively) were generally below their respective reporting limits, or detected at concentrations that are substantially lower than their parent compounds. These findings suggest that the aquifer characteristics are not ideal for promoting the rapid and complete sequential dechlorination of the parent contaminants.

Biodegradation/natural attenuation data collected during February 2003 indicate that significant dechlorination to innocuous end products for the chloroethene contaminants (e.g., ethene) and chloroethane contaminants (e.g., ethane) is not evident. Low concentrations of ethene at source area monitoring well OW1 (1.4 ug/l) and OW8 (1.0 ug/l) suggest limited potential for complete detoxification of the chloroethene contaminants through the reductive (anaerobic) pathways considered in this evaluation (see Tables 3-8 and 3-9 for biodegradation and natural attenuation results). Similarly, low concentrations of ethane at source area monitoring well OW1 (3.2 ug/l) and OW8 (0.036 ug/l) suggest limited detoxification of the chloroethane contaminants through reductive dechlorination processes. Limited detoxification of the chloroethene and chloroethane contaminants through reductive processes is likely due to the absence of sufficient electron donor compounds (i.e., typically measured as DOC) to drive the groundwater environment to highly reduced conditions (e.g., sulfate reducing and methanogenic) and provide the necessary source of energy to

fuel contaminant dechlorination reactions. The presence of elevated DO concentrations recorded in February 2003 at OW-8 (1.57 mg/L) and OW-4A (3.29 mg/L), and elevated nitrate concentrations at OW-4A (11 mg/L), suggests the presence of oxidized groundwater reducing environments and electron acceptors that compete with the dechlorination of the chloroethene and chloroethane contaminants. Sulfate data collected in February 2003, which also competes with the contaminant dechlorination reactions, were elevated and ranged from 162.5 mg/L to 347.5 mg/L at the OW-1, OW-4A, and OW-8 monitoring wells.

The occurrence of these competing electron acceptors may be overcome through implementation of active remediation systems that can reduce the concentrations of these naturally occurring compounds and provide the necessary energy to promote the rapid and complete detoxification of the chloroethene and chloroethane contaminants. While biodegradation of some VOC daughter products (e.g., VC and chloroethane) to innocuous carbon dioxide may also occur through oxidative processes under aerobic and iron-reducing conditions that were not discussed in this section, the ability for such reactions to provide a meaningful approach to remediation would require an abundance of daughter products relative to parent compounds since the parent compounds and some intermediate compounds (e.g., PCE, TCE, cis-1,2-DCE, and DCA) generally persist under oxidized environments.

In summary, results from this screening level evaluation of intrinsic biotransformation processes suggest that active dechlorination of the primary chloroethene and chloroethane contaminants is occurring; however, complete and rapid detoxification of these contaminants is not evident from the existing data set. Furthermore, while limited detoxification of these contaminants may be occurring through reductive dechlorination processes, as evidenced by the low concentrations of ethene and ethane, the significance of these dechlorination reactions appears to be limited by absence of highly reduced groundwater environments and absence of significant electron donating compounds. While limited detoxification of these contaminants through oxidative processes is possible, the ability of oxidative processes to provide a meaningful approach to remediation is limited by the presence of higher chlorinated contaminants that do not readily biotransform under oxidized environments. Future design of remediation systems to address the chloroethene and chloroethane contaminants should consider biologically-mediated systems that are capable of achieving complete detoxification of these contaminants in-situ, thereby limiting risks associated with other technologies in which contaminant mass is transferred from one media to another.

The contaminant pathway in the shallow aquifer appears to be quite narrow, as evidenced by lithologic and water quality differences observed at the location of well OW8 compared to wells OW2 and OW3. The well pair at OW4a/4b may be located a short distance (approximately 140 to 150 feet) south of the interpreted main contaminant transport pathway. Therefore, well MW4a may be located along the edge of the plume and concentrations at that location may be lower than they would be compared to a well placed 140 to 150 feet to the north. Sampling results from the

proposed OSVOG wells will be used to perform further evaluation of both the shallow and deep flow paths from the Omega Site.

4.1.5 Aquifer Characteristics

Single borehole and multi-well aquifer tests were conducted during these investigations. Estimates of transmissivity were obtained for the upper aquifer in wells along Putnam Street. The most reliable estimates were obtained from the multi-well test. The upper aquifer transmissivity in this area ranged from 563 to 810 ft² /day. Transmissivity increases in the downgradient direction, with a value of nearly 2,700 ft² /day estimated at OW4a. Sufficient data are available to allow design of a hydraulic containment system for the upper aquifer in the vicinity of Putnam Street, focusing on a sand channel deposit that appears to be transmitting the majority of the contaminant mass from the site.

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4.2 Recommendations

Earlier conceptual designs for the groundwater treatment plant considered treatment for VOCs only. With the detection of relatively high concentrations of 1,4-dioxane in the on-site source area well (OW1) and elevated concentrations in the downgradient Putnam Street well (OW8), additional treatment requirements need to be considered. The compound 1,4-dioxane is not readily strippable or absorbed by granular activated carbon (GAC), therefore, alternative treatment methods (e.g., ultraviolet-oxidation [UV-OX]) need to be evaluated to address the detection of this compound.

Section 5

References

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Appendix A

Boring/Well Construction Logs, MIP

Screening Results, and Electric Logs

CDM

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Appendix B

Completed Field Forms

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Appendix C

Well Survey Data

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Appendix D

Analytical Reports and COCs

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Appendix E

Aquifer Test Data

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Appendix F

Fate and Transport

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Appendix G

Hydrographs and Time-Series Plots

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Appendix H

Data Validation Results

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